Multispectral Aerial Photography as Land Quality Indicator for Maize Growth in the Limagne Area

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1. Abstract

Multitemporal MSP (MultiSpectral aerial Photography), supplemented with field reflectance measurements, provides quantitative data on crop growth if expressed by a vegetation index, which is linearly related to the Leaf Area Index.

The use of MSP, acquired at three different dates of which two were in the growing season of maize, is evaluated for land evaluation of four study areas in Limagne. The areas contain the three main soil types of the region: alluvial soils of the Allier Low Terrace, brown calcareous soils of the hills and black soils of the Marais.

MSP imagery of July and August showed reduced growth at the start of the growing season on black soils of the Marais as well as a strong effect of slight drought on soils in stony gullies of the Allier Low terrace and on shallow soils of the hills.

Limitations for maize growth were found to be in the domains of water availability, nutrient availability, resistance to compaction, workability and oxygen availability. After a first qualitative land evaluation, data on MSP-derived WDVI (Weighted Difference Vegetation Index) were used as Land Quality indicators to arrive at an appraisal of land suitability for maize growth, taking into account soil variability and where necessary complexes of limitations.

Key words: remote sensing, multispectral aerial photography, land evaluation for maize growth, land quality indicator.

2. Introduction

Multispectral data can be used to characterize plant cover, since reflectance of visible and near infrared radiance has a direct relation with leaf pigments, leaf morphology and the water content of the leaf (Bunnik, 1978).

All leaf pigments absorb light at 430-440 nm, but chlorophyll has an additional absorption band at 660 nm. Reflection of green radiation (550 nm) is caused by the chloroplasts. The range between 700 and 1300 nm is characterized by very little absorption and relatively high reflectance by plant canopies. However, this range is sensitive to changes in morphology such as caused by wilting (Mulders, 1987).

By and large, the condition of the canopy can be characterized by multispectral observation.

In land evaluation, assessment of land qualities involves rating of specific land characteristics (checklist in FAO, 1983; relation with land qualities, Sys et al., 1991).

Uncertainty exists in estimating land qualities, considering the effects of soil variability and the possible interaction of land qualities (Van Diepen et al., 1991). For agricultural use, the application of crop growth simulation models enabled a quantitative approach to land evaluation (Bouma, 1989: Driessen and Konijn, 1992). Both the estimation of land qualities and crop growth simulation models are served by remote sensing, producing a report on crop growth over a particular growing season (crop growth monitoring with the use of remote sensing: Van Leeuwen, 1996). Therefore, remote sensing results can be used as land quality indicators (for general concept: Pieri et al., 1995).

The report can be obtained by multitemporal multispectral observation. In the near future, it is expected that satellite data will become available with ground resolution cells of sufficient detail. At present, remote sensing at detailed scales is done with airborne sensors, e.g. fultispectral scanning from aerial platforms, true and false colour aerial photography, multi-spectral aerial video imagery (Kramber et al., 1988) and MultiSpectral aerial Photography or MSP, often supported by measurements on field reflectance.

Various applications of these techniques are found in literature:

- fertility assessment from true colour aerial photography (Feng Zheng and Schreier, 1988);
- MSP e.g. to detect treatment effects in cereals (Clevers 1986-a) or for correlating gray tones of maize with available water in the soil profile (Stein et al., 1989);
- field reflectance data as input for a model on potato yield (Finke, 1992).

MSP was selected for the present study because of its high spectral resolution with specific films and filters and acceptable costs. The following research objectives were pursued:

- detection of reduced growth by multitemporal MSP;
- the use of MSP for a report on the effect of soil variability and slight drought on crop conditions in selected areas;
- the application of MSP data in land evaluation.

3. Study Areas, Key Areas, Climatic Conditions and Qualitative Land Evaluation

The Limagne Basin was formed in the Eocene-Oligocene; it is surrounded by Hercynian Basement (Fig. 1). Volcanism took place after the formation of the basin.

The Allier with well developed terraces and the so-called Marais dominate the landscape, alongside, besides volcanic landforms. The Marais were most likely originally thermokarst lakes, which were filled up with peat and clay during the Holocene (Kroonenberg et al., 1987).

The climate is characterized by a warm summer with occasional rains and a cool humid winter. Precipitation and temperature from April to the end of November 1988 are given in Fig. 2. The summer of 1988 showed a relatively dry spell.

Land use in the area is concentrated on the growth of maize and cereals as well as animal husbandry.

Four study areas were selected (Fig. 3), these being: Culhat, Vinzelles, Tinlhat and Marais. Bornand et al. (1968) indicate the following soil types:

- alluvial soils of the Allier Low Terrace (AC profile), present in the Culhat and Vinzelles study areas;
- brown calcareous soils on hill slopes (AC or A(B)C profiles) in the Tinlhat study area;
- hydromorphic soils with accumulated organic matter (AC or A(B)C profiles) in depressions of the Tinlhat study area;
- black soils (Isohumic soils) and calcareous soils (AC or A(B)C profiles) of the Marais (location in Fig. 1).

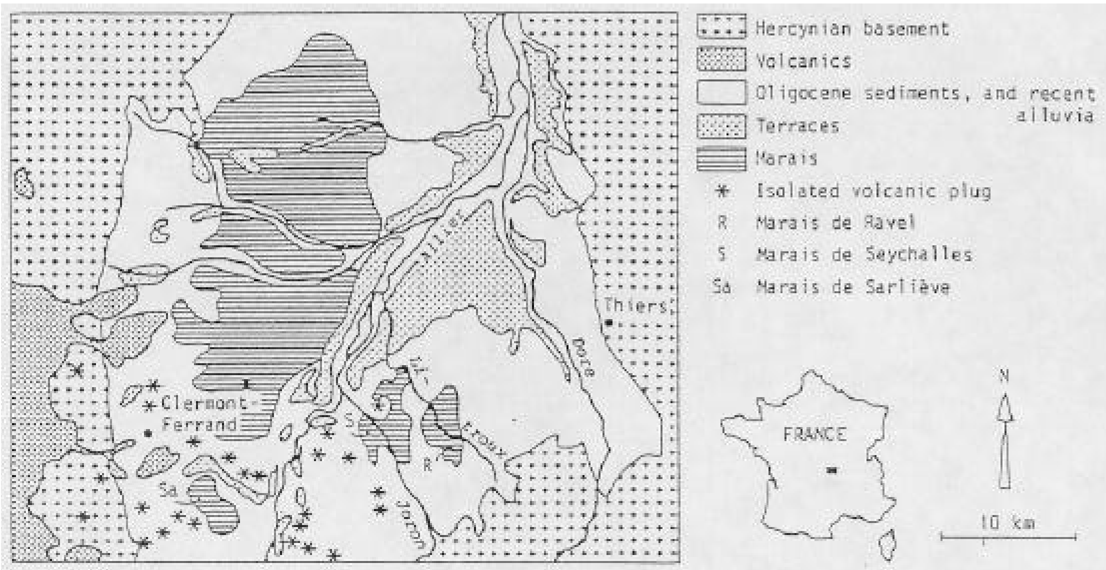


Figure 1. Geology of the Limagne Basin, France (Kroonenberg et al., 1987).

In each of the study areas, one parcel with maize was selected for detailed study. Different varieties of maize were grown on these parcels e.g. variety "DEA" in Culhat, LG 22-50 on the Marais (St. Ignat) and hybrid variety INRA 2080 in Tinlhat. The DEA and LG 2250 varieties have productions, which only differ 2-3 % from average (of 5 yrs and 11 var. acc. M. Billaud/ acknowledgements). The relative production of INRA 2080 is unknown. Fertilizing was supposed to be adequate for maximum yield of grain maize on the soils under consideration; more fertilizer was supplied on the soils of the low terrace, compared to the others. Crop rotation of maize with cereals, sunflower (or other crop) was practiced. Except for Culhat (irrigated maize), it concerned rainfed agriculture.

After description of soil pits, soil samples were taken and analyzed in the laboratory; the soil profiles were classified according to the legend of the Soil Map of the World. The soil characteristics in the key areas are summarized in Table 1.

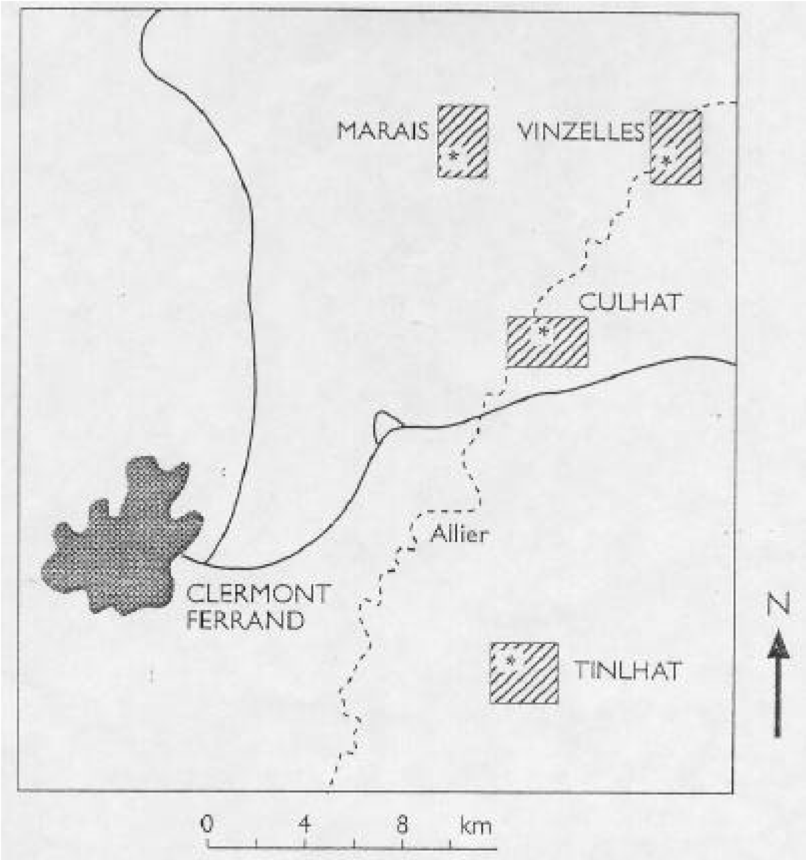


Figure 2. **Location of study areas near Clermont Ferrand (France): Culhat, Vinzelles, Tinlhat and Marais. (* key areas).**

Table 1. **Summary on soil characteristics of the key areas**

General characteristics

Key areas	Physio-graphy/ slope	soil unit SMW*	Soil texture	soil varia-bility#	drainage condition init. moist	fertil. status	Permea -bility
Culhat Vinzelles	Low terrace** 0-1 %	Eutric Cambisols+	Loam Sandy loam loamy sand sand	gravel beds^	well drained 22 %	Moderat e	high
Tinlhat	Lower slopes hilly land 2-4 %	Calcaric Regosols	Clay loam clay	depth	well drained 38 %	High	moderate "
Marais	Plain 0-1 %	Eutric Fluvisol	Silty clay clay loam	depth of olive clay loam	imperfect-ly drained 50 %	high	low'

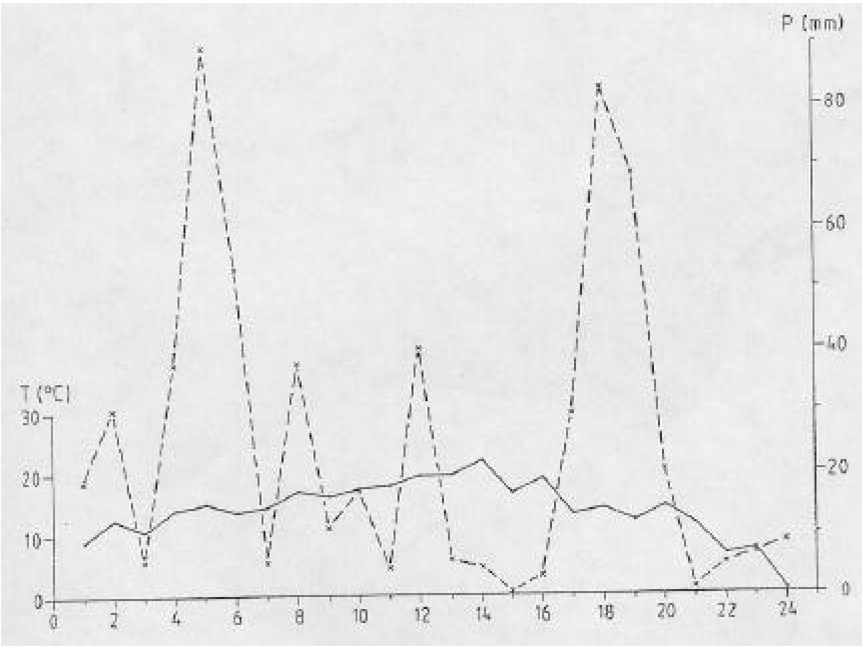
*	SMW or Soil Map of the World (FAO, 1988)
#	with supposed adverse effects on maize growth
init. moist.	initial (18 May) soil moisture content
**	slight risk of flooding
+	Jongmans et al. (1991)
'	weakly developed soil structure
"	well developed soil structure
^	with stones and fine earth with sandy loam texture

Soil analytical data of dominant soils

key areas	depth cm	% sand	% clay	PH H_2O	Sum of cations cmol/kg	base saturation	organic carbon %
Culhat	0-40	43	19	6.9	10.4	80	1.5
	40-75	45	18	6.9	10.8	86	1.1
Vinzelles	0-40	44	19	6.8	7.8	78	1.1
	40-75	45	15	7.0	5.8	73	0.6
Tinlhat	0-40	14	50	7.8	23.2	100	1.5
	40-75	16	52	7.9	23.4	100	0.8
Marais	0-40	10	50	8.2	27.6	100	1.9
	40-60	3	39	8.2	36.8	100	2.4

3.1 Qualitative Land Evaluation for Maize

The precipitation during the growing cycle of maize in Limagne (May-September) amounted to 410 mm; the mean temperature in that period was 18 ^{o}C. This is lower than the optimal water supply in the growing season and only just within the range of optimum temperatures for germination, given by Sys et al. (1993). Based on these data, the climate has to be regarded as moderately suitable for maize cultivation.



decades	month	decades	month	Temperature ^{o}C
1-3	April	13-15	August	
4-6	May	16-18	September	x Precipitation (mm)
7-9	June	19-21	October	
10-12	July	22-24	November	

Note:Courtesy "Centre Departemental de la Meteorologie (Clermont Ferrand)"; Chappes is located 14 km north-east of Clermont Ferrand (France).

Figure 3. Average temperature and precipitation for decades in the period April-November 1988 at Chappes.

Considering the data given by Sys et al. (1993), the following land characteristics are supposed to offer limitations (rate 1-3: slight-moderate-severe) for maize growth in the study areas:

- flooding hazard (1) for Culhat and Vinzelles;
- drainage (2) for Marais;
- pH H_2O (2) for Tinlhat and (3) for Marais;
- slope (1) for Tinlhat;
- sum cations, base saturation, organic carbon (1) for Vinzelles.

A qualitative suitability rating would be: 1) S2n Tinlhat (ignoring the slight limitation of slope); 2) S2mf Culhat; 3) S2mnf Vinzelles; 4) S2conw Marais, where S2 = moderately suitable; the limitations are m = moisture availability, n = nutrient availability, f = flooding hazard, o = oxygen availability in the root zone, c = resistance to compaction and w = workability (FAO, 1976). However, this evaluation produces uncertainty since the effects of different land characteristics, including soil variability (Table 1), are not taken into account and the effects of land qualities on crop productivity on different land and soils are unknown. The same applies for interactions of the parameters used for evaluation. To arrive at a more quantitative approach to land evaluation, multitemporal MSP data are used to produce a (two dates) report on crop condition and to calculate the degree of limitation.

4. Remote Sensing Methods

MultiSpectral aerial Photography (MSP) was acquired with a CESSNA 172 aircraft, equiped with two Hasselblad cameras (Zeiss Planar 80 mm lens), at three different dates in the year 1988: 9-10 July, 17-18 August and 11 November. The first two acquisitions were in the growing season of maize (sowing at the end of April and harvesting in the first half of October). The last acquisition of photography was after harvesting of maize and represents a bare soil.

The films and filters, which were used, are given in Table 2.

Table 2. Films and filters used for MSP acquisition

KODAK 70 mm Films	Kodak filters *	Wratten	Colour > 50 Transmission	bandwidth nm
PX 2402	47B	blue	410-460	50
PX 2402	21 + 57 A	Green	555-580	25
PX 2402	70	dark red	665-700	35
IR 2424	87 C	near infrared	840-900	60

*** Eastman Kodak Co. (1970).**

The translation of photodensity to reflectance values was done using methods developed by Clevers (1986-a) and by Loedeman et al. (1986). Polynomial fitting of the characteristic curves from the PX 2402 and IR 2424 films produced formulae, which enabled to calculate the relative exposure values of the image plane (Q) from photodensity (acknowledgements: Nooren, 1991). In the same way, the percent of light fall-off of the 80 mm lens at relative apertures of 2.8 and 5.6, used in the acquisition of the aerial photographs, was estimated from plots of the relative illumination (E) and the distance from the center of the image plane. The relative exposure values thus can be corrected for light fall-off to produce Qc values. To correct for differences in illumination and processing, the Q_c values were expressed in percent of Qmax (Q %). Linear regression of Q% with a set of reflectance data, measured in the terrain, produced formulae to calculate spectral reflectance, derived from MSP data.

Spectral reflectance data can be correlated with the leaf area index (LAI) of the crop under consideration. For this the simplified reflection model, developed by Clevers (1986 a-b, 1988) and applied by Finke (1992), was used. In this model, a so-called corrected near infrared reflectance factor is related to LAI by an equation that contains two parameters that have to be estimated.

The corrected near infrared reflectance or WDVI (Weighted Difference Vegetation Index acc. to Clevers, 1993) is equal to:

$$WDVI = r_{ir} - (c \times r_r) \qquad (1)$$

where r_{ir} and r_r represent the total measured reflectance for resp. near infrared and red; $c = r_{s,ir} / r_{s,r}$, where $r_{s,ir}$ and $r_{s,r}$ are the soil reflectance factors for resp. near infrared and red.

There is a linear relationship between WDVI and the fraction of absorbed photosynthetical active radiation and of the latter with yield (Clevers et al., 1994; Clevers, 1995).

5. Results and Discussion

5.1 Interpretation of MSP for Detection of Reduced Crop Growth

Multispectral photographs of maize fields taken with different filters produce effects, which require knowledge of reflectance. For example, reduced crop growth results in lower absorption of visible radiance due to smaller leaf area and lower coverage, thus higher reflectance of visible radiance.

In the Vinzelles key area, pronounced contrast is found on the MSP of the flight of August. Fig. 4-b obtained with a green filter shows more contrast than 4-a (flight of July). The patterns present in the maize field are gully patterns in the Low Terrace of the Allier. The soils in these former gullies are rich in stones and gravel and consequently crops showed reduced growth mainly caused by moisture deficit.

Effects are different for the bands in the visible and near infrared. The near infrared photograph Fig. 4-c is the opposite in gray tone of the other two of 1st and 2nd flight, since reduced crop growth in the gullies means reduced reflectance in near infrared and thus a dark gray tone. A high crop coverage causes a high near infrared reflectance (light gray tone).

MSP provided for evidence on the effect of soil depth on crop growth. A parcel with sunflowers on a hill slope in the Tinlhat area, showed at its upper part of slope a low near infrared reflectance (dark gray tone) at the end of the growing season (Fig. 5). Although less pronounced, adjacent maize parcels also showed reduced growth on the upper slope. The phenomenon is caused by reduced growth due to the low available water capacity of the shallow soil at that site. It is not visible on an aerial photograph acquired with the same filter during the 3rd flight, showing the bare soil condition.

From the latter, it is apparent that MSP of parcels covered by growing crops can make visible what is hidden in bare soil condition.

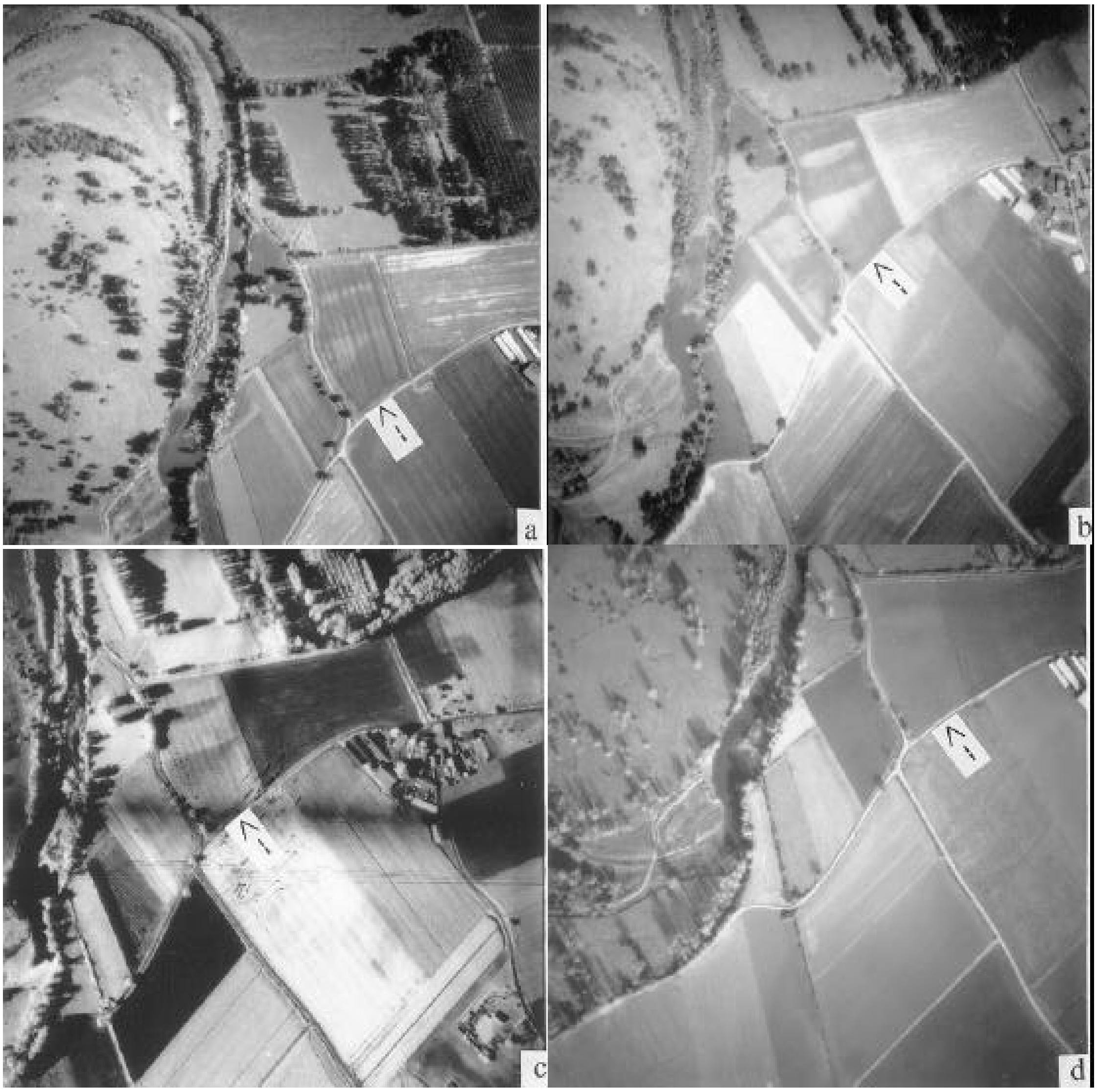


Figure 4. Multitemporal multispectral photographs of the Vinzelles key area. Aerial photographs: a) green filter 1st flight (July); b) green filter 2nd flight (August) c) near infrared filter 2nd flight (August); d) green filter 3rd flight (November).
Key area: -->

The opposite may be observed as well. During the research in the Marais area, traces of roads and ditches (former parcel boundaries) visible on imagery of the third flight did not have any effect on plant growth, as witnessed by their absence on photographs taken when the soil was covered by maize.

Furthermore, no evidence was found by MSP on the supposed negative effect on crop growth of the olive clay loam in the Marais subsoil (Table 1). This clay loam was without structure and occurred at various soil depth with as intermediate 50-70 cm below the soil surface (Mulders, 1992).

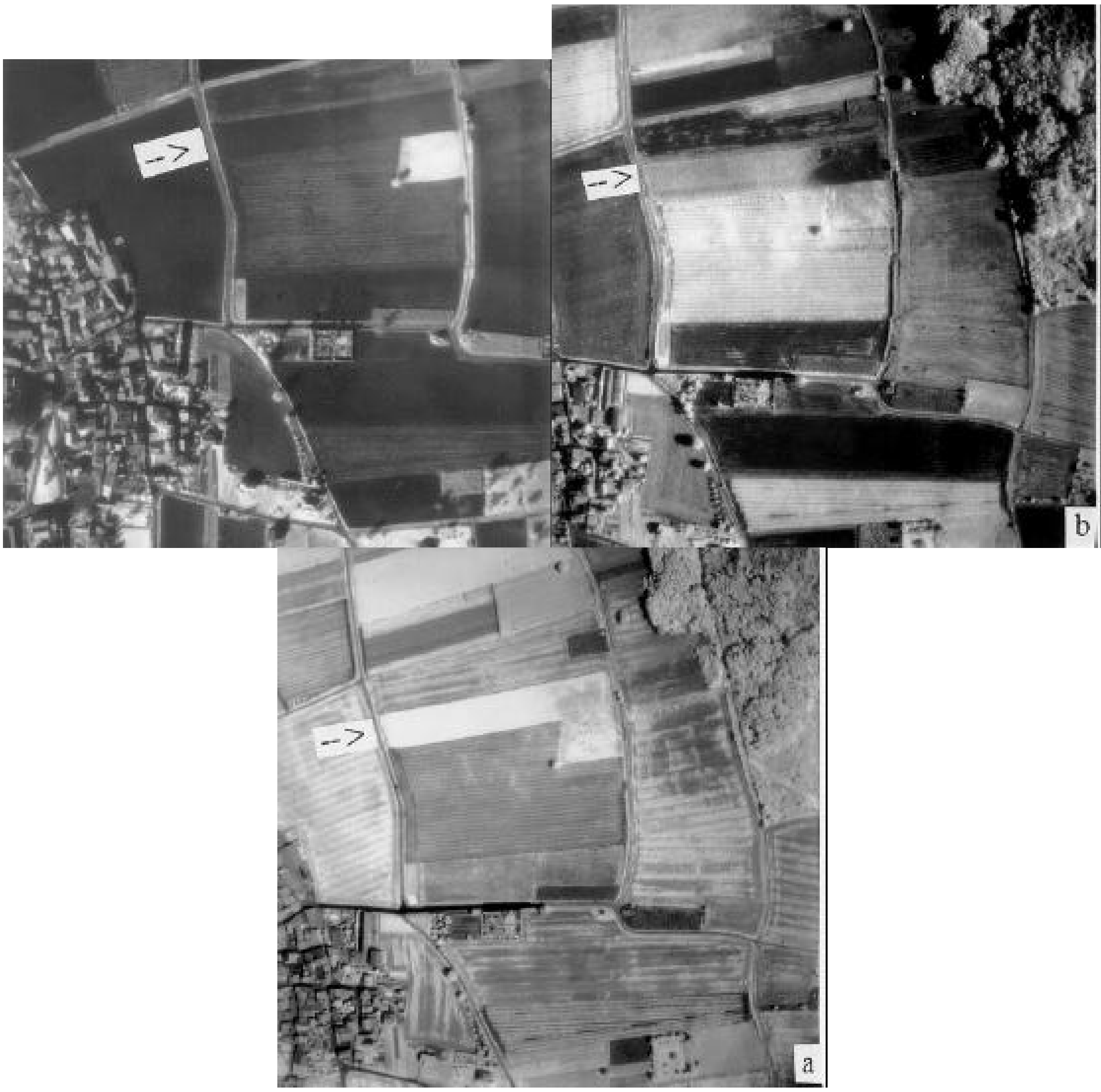


Figure 5. Multitemporal near infrared photographs of a field with sunflowers in the Tinlhat area. The effect of shallow soil is most pronounced on 2nd flight photography. Aerial photographs: a) 1st flight (July); b) 2nd flight (August); c) 3rd flight (November).

5.2 Report on effect of soil variability and drought on crop condition.

MSP data of the 1st and 2nd flights were translated into reflectance values to study the effects of soil variability and drought on crop condition.

For calculation of the WDVI, data on soil reflectance at different soil moisture contents were used to estimate average c-values of the study areas: 1.18 (Culhat), 1.26 (Vinzelles), 1.29 (Tinlhat) and 1.31 (Marais). The calculated dominant and deviating WDVI values are given in Table 3.

Table 3. WDVI of 1st and 2nd flights

key area	flight	WDVI dom.	% area with deviation	WDVI dev.	WDVI key area
Culhat	1st	31.7	3	28.6	31.6
	2nd	27.3	8	23.4	27.1
Vinzelles	2nd	20.7	22	8.4	18.0
Tinlhat	1st	33.8	5	29.2	33.6
	2nd	38.5	1	34.2	38.3
Marais	1st	15.6	17	9.6	16.9
	2nd	17.3	11	13.9	17.0

The report using climatic data and MSP data of two acquisitions during the growing season of maize, as indicative for crop condition, focusses on the following issues:

- identification of soil pattern and variability by MSP;
- effect of soil variability of different soil types on maize growth;
- effect of drought on maize growth;
- evaluation of statements made on the limitations in qualitative land evaluation.

From the interpretation of MSP, it became evident that the soil patterns of stony gullies in the Allier Low Terrace and of shallow soils in the Tinlhat area causied a moisture deficit later in the growing season. They are detectable in places under crops, using MSP of August (2nd flight). These deviations of dominant soil types were considered as soil variability of which the pattern is detectable with accuracy.

Other deviations are caused by soil variability due to compaction after tillage, the degree being dependent on soil type and climatic conditions as well. Their effect was quite severe in the Marais key area (Table 3, high % of surface with deviation and low WDVI of deviations). This is related to the initial high soil moisture content (Fig. 5) and imperfect drainage (Table 1). This initial high moisture content caused limitations in availability of oxygen as well as a relatively low temperature, unfavourable for germination. The growth of maize in the Marais area was lagged in July: low dominant WDVI value at 1st flight, despite the high fertility status (Table 1). Later in the growing season, a large part of the area recovered: lower % of surface with deviations at 2nd flight), growth picked up but was still behind that of the Culhat and Tinlhat key areas, according to the WDVI values (Table 3).

Fig. 2 indicates the occurrence of a slight drought in the decades 13-16 (August-1st decade September). Where soils have limitations in moisture availability because of their moderate content of clay (Table 1: Culhat and Vinzelles), this shows up in the MSP data of the 2nd flight (August 17-18). It actually helps to explain the decline in dominant WDVI values from 1st to 2nd flight, despite irrigation in the Culhat key area. The key areas with heavier texture and higher available water holding capacity show an increase in WDVI from 1st to 2nd flight (Table 3: Tinlhat and Marais). Soils in these key areas had a high moisture content at 2nd flight.

In qualitative land evaluation, climatic restraints were supposed to force the best soil in suitability class S2 (ref. Sys et al., 1993). However, the climatic restraints can be waived since yields are in the key areas are above (the lowest value of) 6-9 tons/ha grain maize, considered as a good commercial yield.

The supposed negative impact of high pH on uptake of nutrients is not evident for the Tinlhat key area but may be valid for soils of the Marais key area. The results of the report confirm the assumed limitations of oxygen availability, resistance to compaction and workability in the Marais area.

Furthermore, strong evidence was found for limitations of moisture availability in the Culhat and Vinzelles key areas.

5.3 Yield Estimates and Land Evaluation aided by MSP

The R square values of linear regression between actual yield (data from farmers and from plot measurements) with the WDVI values, presented in, are: 0.79 for 1st flight and 0.93 for 2nd flight. For values on predicted yield, see this Table. In the Tinlhat key area, maize is grown for seed production; actual yield will be lower than under normal management as given in the Table.

For land evaluation, the funding on the studyareas has to be extrapolated to the surrounding areas. For dominant soils, the key areas are representative for the areas of Culhat, Vinzelles and Marais.

The key area of Tinlhat is representative for the lower hill slopes of the area. The other two main units of the study area, which are upper slopes with 10 % shallow soils and depressions with soils rich in organic matter, are not considered in the evaluation.

The extent of gully systems with adverse properties for the growth of maize was estimated in the study areas Culhat and Vinzelles by studying MSP data. These are:

- Culhat, 10 % of the surface;
- Vinzelles, 15 % of the surface.

To estimate the adverse effect of the gully systems, actual harvest was recorded in the Culhat area. The gullies showed a reduced maize grain production of 55 % compared to the rest of the area (data of 1992).

The WDVI values of Table 3 are used to evaluate the effect of soil variability on land qualities The dominant WDVI for general limitations is considered valid for general limitations of dominant soil types. WDVI of deviations is useful when studying the effects of soil variability.

Calculated yield, classified WDVI values of the difference between 2nd and 1st flights and WDVI values of the 2nd flight are given in Table 4. This Table, also allows conclusions on the type of limitation and it allows to make a final rating of limitations taking into account soil variability of the study areas.

In Table 4, the degree of limitation is set equal to:

$$[(2 \times \text{WDVI 2nd fl.}) + (\text{WDVI 2nd - 1 st fl.})] : 3 \qquad (2)$$

In this way, more emphasis is given to the WDVI value of 2nd flight (well correlated with yield), than to the difference in WDVI, which stands for crop development from July-August. The final estimates of limitations, calculated for the study areas [using equation (2)] take into account the contribution of soil variability (deviations).

Table 4. Yield, WDVI values classified for limitations and suitability of the study areas

study areas	calc. yield t/ha	WDVI dom. 2nd-1st	WDVI dom. 2nd	dom. lim.	WDVI dev. 2nd-1st	WDVI dev. 2nd	lim. dev.	% area with dev.	suit. and lim.
Culhat'	10.4	3	1	$m_{1.7}$	3	2	$m_{2.3}$	10	$S2m_{1.8}$
Vinzelles	7.8	3"	2	$m^*_{2.3}$	3"	4	$m^*_{3.7}$	15	$S3m^*_{2.5}$
Tinlhat	14.9	0	0	Non	0	0	non	5	S1
Marais	7.1	1	3	$C^*_{2.3}$	0	4	$c^*_{2.7}$	17	$S2c^*_{2.4}$

' irrigated maize cultivation, others are rainfed.
" interpreted value.
m major limitations in water availability
m* major limitations in water availability and minor limitations in nutrient availability
c* major limitations in resistance to compaction, workability and oxygen availability

The classification of WDVI values was done as follows:

limitations		WDVI values	
dig.	**type**	**2^{nd}-1^{st}**	**2^{nd}**
0	no	> 3	> 30
1	slight	0 to 3	25 to 30
2	moderate	-3 to 0	20 to 25
3	severe	-6 to -3	15 to 20
4	very severe	< -6	< 15

The indexes m, m* and c* stand for:
- M: major limitations in water availability;
- m*: major limitations in water availability and minor limitations in nutrient availability;
- c*: major limitations in resistance to compaction, workability and oxygen availability.

Major limitations can be indicated but the effect of the minor limitation of nutrient availability on crop growth, contained in m*, could not be indicated separately.

Not detectable with this data set is flooding hazard in the Culhat and Vinzelles areas and the effect of nutrient availability on crop growth in the Marais area.

The outcome suggests that the suitability of the Marais area is just inside the S2 suitability class limits. The recovery of growth observed in the 2nd flight is in support of this result.

The conclusions made in the report introduce ‘conditions of germination’ as a constraint for maize growth in the Marais study area.

Below, the final suitability is given in with limitations of which the degree is not known indicated between brackets (where g stands for limitations in conditions for germination):

- Irrigated grain maize cultivation
  - Culhat -- $S2m_{1.8}$(f)

- Rainfed grain maize cultivation
  - Vinzelles -- $S3m^*_{2.5}$(f)
  - Tinlhat -- S1
  - Marais -- $S2c^*_{2.4}$(n,g)

6. Conclusions

Qualitative interpretation of MSP sheds light on crop growth on different soils with different soil variability. The latter may be best detected by studying MSP acquired when the soil is covered by vegetation after comparison with MSP of bare soils. Particular phenomena affecting plant growth may remain hidden if bare soil condition or phenomena visible on MSP of bare soils may have no effect at all on plant growth.

The MSP data provided evidence on supposed negative effects on crop growth, such as that of former gully bottoms and depth to the olive gray silty clay in the Marais soil. Evidence of the negative effect of gully bottoms was found by MSP but no evidence of any negative effect was found in the case of the olive gray silty clay.

The qualitative interpretation of aerial photographs and field observations, aided by MSP data, enable to select parcels or key areas, which represent the general soil condition or areas for studying specific effects (such as irrigation). The quantitative approach was directed towards the growth of one specific crop (maize) on these parcels, enabling through the use of WDVI a rating of suitability of different soils and areas.

The final suitability rating differs considerably from the qualitative land evaluation. It became apparent that land qualities may be interacting and it was not possible to discriminate them individually. In particular:

- water availability and nutrient availability in case of gravel beds (gully systems);
- resistance to compaction, workability and oxygen availability in case of heavy textured soils
- imperfect drainage and low permeability.

MSP enabled to quantify the degree of limitations of the most important land qualities (Table 4: unique or combined) under the climatic conditions of the acquisition period. These land qualities and the interaction of land qualities may be subject of further research. Some of these land qualities are related to climatic conditions and new acquisition of MSP may be a solution provided that the climatic conditions are different from those of which the effect is already studied.

Experiments have to be considered as an alternative. The present method offers as a possible outcome: the definition of master factors, which can be used for definition of experiments needed for a quantitative approach.

Based on the experience obtained by this study, the MSP needed in support of land evaluation is defined as follows:

- two band-pass filters are sufficient, namely near infrared and red; two Hasselblad cameras mounted in light aircraft can be used to fulfil this requirement;
- for a report on crop growth, two acquisitions of MSP are required, namely early in the growing season (3rd decade of June and the month July) and late in the growing season (2nd-3rd decade of August);
- for comparison of bare soil with soil covered by crops, one acquisition just after the growing season (e.g. November) is wanted in addition.

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